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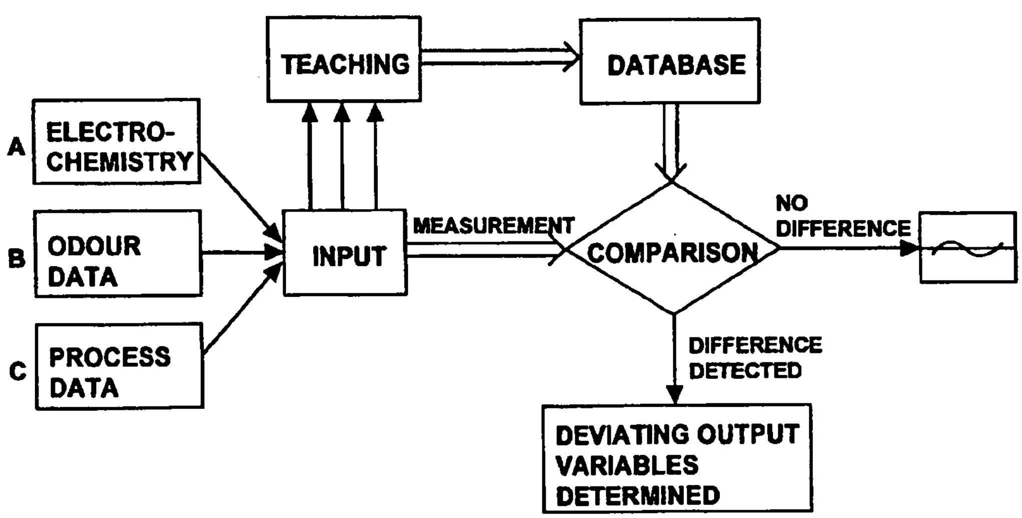
(54) Title: METHOD FOR ANALYSING A PAPERMAKING PROCESS AND AN ELECTROCHEMICAL SENSOR FOR ANALYSING LIQUID



(57) Abstract: The invention relates to a method for analysing a papermaking process, in which several electrochemical quantities are measured from at least one liquid flow and fingerprints according to good process situations are determined. The electrochemical measurements are carried out independently of each other using at least three electrode series, each comprising at least three electrodes. In addition, at least one odour measurement is used from the gases that are emitted from the said liquid flow into the gas space over the free liquid surface.

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METHOD FOR ANALYSING A PAPERMAKING PROCESS AND AN ELECTROCHEMICAL SENSOR FOR ANALYSING LIQUID

The present invention relates to a method for analysing a papermaking process, in which several electrochemical quantities are measured from at least one liquid flow in the process and various fingerprints according to the process situation are defined, to which the fingerprints obtained in a normal process situation are compared and the differences creating an essential difference in the initial quantities are defined. The invention also relates to, for implementing the method, an electrochemical, i.e. polarographical/galvanostatic sensor for analysing liquid. The invention particularly relates to papermaking processes, but the study of environmental waters, for example, may also be considered.

Neural networks, i.e. neural calculation, is used for the analysis of various processes. One known neural network model is SOM (self oriented map). Such algorithms are used to form a database from the vectors of the output variables, with the aid of various process situations. Measurement vectors, which are compared with the vectors in the database, are calculated from the measurement values obtained in the process situation. If these deviate by certain criteria from all the vectors, an attempt is made to analyse what difference or differences in the output variables caused the difference in question.

Often when applying the neural network technique, a large number of process variables are included, but the results are not satisfactory. Apparently, some of the output variables have been particularly unstable, in which case they have upset the study, and have not properly represented the process situation.

Patent publications US 4,818,348; 4,830,343; 5,393,399; 5,654,497; and EP 692711 disclose some liquid analysers that use polarographic sensors. In the first publication referred

to, the liquid is vaporized and the vapour is led through parallel sensors. Finnish patent application 892351 also discloses a disposal electrochemical sensor, which is intended for medical use. The generally known sensors have a narrow area of application and they are usually only able to measure a few predefined substances and their contents in a liquid. A sensor according to publication US 5,830,343 will not remain in operating condition for long, because even individual fibres can cause a short-circuit between the electrodes of the tiny sensor.

The present invention is intended to create a new kind of method and electrochemical sensor for it, in which the method provides better and more stable results that previous solutions.

The characteristic features of the method according to the invention are stated in the accompanying Claim 1 and the characteristic features of the electrochemical sensor to be used in the method are stated in Claim 5. Electrochemical measurements provide certain voltage levels. According to the invention, what substances or compounds create the responses obtained are not, as such generally determined, though this is, as such, possible. Instead, so-called 'fingerprints' for specific process situations are obtained from the measurements. These can correspond to either good or bad situations. The scope of application of the method expands considerably if, in addition to the electrochemical measurements of the liquid flow, odour measurements are made from the gas released from the liquid flow. This is because it has been observed that the powerful effects of some compound may be easily visible from the 'odour vector', even though a relatively faint response is detected when investigating the liquid. Such odour vectors are provided by, for example, bacterial growths, extractives, or certain surfacing substances. The odour is studied from the liquid in such a way that the vapour of the liquid is allowed

to be released, for example, into an air space, in which an odour sensor is located. One such odour sensor is disclosed in, for example, WO publication 97/05476. It is often advantageous to measure the odour sample at different temperatures, for example, at 50°C, 70°C, and 100°C.

Electrochemical measurements generally require the stabilization of the sample and often the use of several pairs of electrodes, but in this case this is not necessary, as long as the changes are measured and the data obtained is used in neural network calculation. The measurement cells formed by the pairs of electrodes, and generally also the pH and temperature sensors form a basic result space of the sample, to which the data from the odour measurements are added. Preferably, the electrochemical measurements are made in a multi-sensor matrix, in which the pairs of electrodes are arranged radially in relation to the input channel, in which a common bias-electrode is located. By this means, the measurements do not interfere with each other and the liquid has the same properties in each measurement. There are at least three, and preferably four electrodes in the series. There are at least three measurement cells, if an odour sensor is included, otherwide 4 - 15, preferably 6 - 10.

In the following, the invention is illustrated by reference to the accompanying figures, which show one method according to the invention and the sensor and program used in it.

Figure 1 shows a neural network model for analysing a process
Figure 2 shows the flow chart of an electrochemically measured liquid
Figure 3 shows a cross-section of a multi-detector sensor
Figure 4 shows a transverse section of the multi-detector sensor of Figure 3 at the point IV - IV of Figure 3
Figure 5 shows a top view of the rotameter system of the sensor of Figure 3

Figure 6 shows the rotameter system of the sensor of Figure 3
Figure 7 shows the electronic circuit card of the multi-detector sensor

The measurement apparatus according to the invention comprises an intelligent on-line sensor, by means of which monitored substances that have dissolved in liquid taken from the process and changes in their contents are detected, without, however, identifying these substances. Process situation detection is based on electrochemical phenomena taking place in the working electrodes, on measurements of pH and temperature, and on artificial intelligence implemented with the aid of a computer, which exploits a predetermined database and selected additional information. This may be the plant's normal process data and/or odour measurements from the same liquid.

The detection, according to Figure 1, of process situations takes place on the bases of electrochemical, odour measurement, and process data. The selected data are entered in a neural-network program (SOM or some other neural network program), in which a directional vector is formed in multidimensional space from the measurement results and is compared with vectors, which represent good process situations, and which are in the memory of the apparatus and have been taught to the apparatus. If the vector obtained is sufficiently close to a vector in the library, it is then identified as a good process situation, otherwise a search is made for the differences in the output variables that are causing the problem.

The vector library is formed by searching for good process situations by subjecting the system to selected process situations and saving the directional vectors obtained from them in the memory of the apparatus. The apparatus's memory may contain several hundred such directional vector 'process situation identification traces' formed from these sensor signals. The selection of good process situations can naturally

also take place after the event, after thorough analysis. The apparatus is preferably made to be modular, so that it can be easily adapted to different applications. The measurements sensor is a single compact package containing measurement cells and galvanically insulated electronics. The actual data processing, detection, and maintenance of the directional vector library takes place by means of a separate commercial, high-speed, powerful microprocessor card, such as the PC-104. The other elements are independent packages, which are connected to each other with the aid of a fixed flow channel.

According to Figure 2, the electrochemical measurement liquid-flow circuit includes a valve 12, a sensor unit 16, flow meters 17, a pH measurement sensor 15, and temperature measurement 18.

The sample line is formed to be so spacious and flexible, that it is not even necessary to filter fibrous samples. This avoids the change in samples caused by filtering.

The actual substance detection sensor is preferably comprised of six or more measurement cells, which are located radially around a bias-electrode.

In the arrangement according to Figure 3, the working electrodes 27 in the measurement cell 16 are tuned to be sensitive to the substances to be investigated by using a differential amplifier to feed current through each counter-electrode 29 and a solution to the working electrode 27, until the target potentials are achieved between the working electrodes 27 and the reference electrodes 28. The amount of current is determined by the target potential, the properties of the solution, and the materials of the working electrodes. The target potentials are determined from the polarization curves run using a measurement device. Alternatively, the measurement is carried out galvanostatically, in which case the current value is set to be constant and the voltage responses are measured as

the solution changes. It is advantageous to run small alternating voltage components on top of the direct-current voltage input, as this increases the reliability of the measurement.

The base level of the apparatus's measurement is set, for example, as the current-signal levels of the measurement cells, which are obtained using a pure liquid, for example, water. The base level is updated from time to time in the apparatus's memory, if its rate and degree of change are not greater than the predefined levels. When kitchen salt, for example, is added to pure water, the current-signal levels change in relation to the base level and compared to each other. The added substance and the amount of it are determined from the relative changes in the measurement signals obtained.

Each measurement cell has its own analog measurement electronics card, and the measurements relating to the diagnostics themselves. The analog card is connected by a bus to the computer of the measurement sensor.

The measurements can also be made by using only the voltage differences between the reference and working electrodes, without current input, which provides its own input space.

The software is divided into several different sub-areas: measurement of the rest potentials, running of the polarization curves, learning the substances to be detected and the disturbance substances and the actual process situation detection. The running of the polarization curves takes place by giving the measurement cell the initial and final potentials, the change potential, and the levelling time. The liquid used is a so-called pure liquid for study, for example, pure groundwater. The angle coefficient between the so-called Taffel's straight lines, which depict the concentration in the solution at any one time, can be derived from the polarization curves.

Next, the run is started, when the potentiostat is given the initial potential as the target and the potentiostat runs between the reference and working electrode to the desired voltage, by feeding current through the counter-electrode and the solution to the working electrode. The potential remains in this potential value for the levelling time, after which the current is measured. Next, the potentiostat is given a new target, which is a change potential greater than the previous target value. The potential again remains at this value for the levelling time, after which the current is measured again. This procedure is continued, until the final potential is reached. A curve is plotted from the potential and current values thus obtained, from which the desired target potential can be seen. A target potential from the horizontal part of the polarization curve, in which the electrochemical reactions and thus the current signals provided by the sensor are at a minimum, is selected for each pair of electrodes.

In the teaching and detection situations, the potentiostats are set to these target potentials and the sensor's current signals obtained with these target potentials are the so-called sensor's base level, with which the changes are compared.

The measurement sensor 16 according to Figures 3 and 4 includes a base component 22, a channel plate 20, an electrode cover 19, a circuit card 40, and a cover plate 21. In base component 22, there is an intake channel 23, which, in channel plate 20, divides radially into measurement channels 25, at the ends of which are outlet channels 24 that penetrate the electrode cover. These are joined together in pairs, with the aid of intermediate channels 30, in cover plate 21, in which there are also connections 31, leading away from intermediate channels 30, and to which the rotameters that are disclosed later are connected by means of connectors 32.

Cover plate 20 and electrode cover 19 are made from Teflon. Electrodes 26, 27, 28, and 29 are attached to electrode cover 19 in such a way that one end of them extends to channel 25 and the opposite end can be connected directly to circuit card 40. The said electrodes are set radially according to the flow channels 25. The bias electrode 26 is located at the intake channel 23. It also contains a high-speed temperature sensor (PT-100).

Measurement channels 23, 25, 30 are arranged to be so spacious that even liquid with a fibre content can pass through them without causing a danger of blockage. The radial channels 25 have a diameter of 0,3 - 3 cm, preferably 0,7 - 1,3 cm, while each electrode 27 - 29 protrudes into the channel in such a way that the speed of flow increases substantially at it (15 - 35 %). The surface area of the electrode in the channel is about 1 cm^2. The fibre and filler particles keep the electrodes clean.

A protectively earthed cylinder, which extends to at least one-third of the depth of electrode cover 19, is arranged around electrodes 27 - 29 on the circuit card 40 side. This has been observed to reduce the noise level considerably.

The materials of the pairs of electrodes are selected according to the desired application. What is essential is that each pair of electrodes is separate and measures the properties of the sample in its own voltage range. The electrode materials can be, e.g. platinum, gold, silver, iron Fe_3, iron Fe_2, stainless steel, molybdenum, zink, titanium, cadmium, copper, glass, electrically-conductive plastic, ceramics.

Odour data is gathered from the process liquid by allowing the gases to travel over the free surface of the liquid to a gas chamber, from where the gas is led to the odour sensors.

Figures 6 and 7 show the exit-flow arrangement of the sensor. Flow meters 35, in this case rotameters, are connected by connectors 32 and through exit channels 31 to intermediate channels 30. Regulator valve 35' is used to adjust the flow to be equal in each line. The outlets of flow meters 35 are connected to a single distributor piece 36, inside which a sensor of pH-meter 37 is placed. A common outlet line 38 is connected to the centre of distribution piece 36.

A water trap 39, which prevents the pH-sensor from drying out during a shutdown, is connected to outlet connection 38. In the same way, liquid also remains in the measurement cell itself, preventing electrodes 26 - 29 from drying out.

In terms of the operation of the sensor according to the invention, it is essential that the pre-amplifiers connected to the electrodes are assembled in compact circuit card 40, Figure 7. The electrode series are connected directly to the circuit card's connector series 41, in which there are individual conductor connectors 42 for the electrodes themselves and other conductor connectors 43 for the protective earthing. The preamplifiers are located in the space 44 between the radial series of electrodes, minimizing the connection distance. With the aid of the circuit card, the amplified measurement signals are led to the area 45 outside the sensor frame, in which there are circuits for processing the measurement signals, and output connectors.

Claims

1. A method for analysing a papermaking process, in which several electrochemical quantities are measured from at least one liquid flow and fingerprints according to various process situations are determined, to which the fingerprints obtained in a normal process situation are compared and the differences in the output variables created by an essential change are determined, <u>characterized</u> in that the electrochemical measurements are carried out independently of each other using at least three electrode series, each comprising at least three electrodes, and, in addition, at least one odour measurement is used from the gases that are emitted from the said liquid flow into the gas space over the free liquid surface.

2. A method according to Claim 1, <u>characterized</u> in that the odour measurements are made in at least two temperature ranges.

3. A method according to Claim 1 or 2, <u>characterized</u> in that the measurements are made from at least one liquid flow containing fibres and the measurement channels (23, 25, 30) are arranged to be sufficiently spacious so that liquid containing fibres can pass through them without causing a danger of blockage.

4. A method according to one of Claims 1 - 3, <u>characterized</u> in that there are six electrochemical electrode series (26 - 29) and their outlet channels (24) are connected together in pairs and these pairs are connected in turn through a flow meter (35) to a common outlet line (38).

5. An electrochemical, i.e. polarographic/galvanostatic sensor for analysing a liquid, in which sensor there is a measurement cell, through which the liquid is led and in which there are several electrode series (26, 27, 28, 29) each series including at least a working electrode (28) and a counter-electrode (29)

and a pre-amplifier connected to each series, to amplify a weak measurement signal, characterized in that in each measurement circuit there are at least three electrodes and the series are placed in a manner that is, as such, known in measurements channels (25) branching out of the intake channel (23).

6. A sensor according to Claim 5, characterized in that the branching measurement channels (25) are set radially in relation to the intake channel (23) and the electrode (26) is in the centre of the intake channel (23).

7. A sensor according to Claim 6, characterized in that the said electrode series (27, 28, 29) each include their own reference electrode (28), so that in each measurement circuit there are four electrodes, the central electrode being a common bias-electrode (26).

8. A sensor according to Claim 6 or 7, characterized in that the material of at least one electrode (26, 27, 28, 29) belongs to the group: platinum, gold, silver, iron Fe_3, iron Fe_2, stainless steel, molybdenum, zinc, titanium, cadmium, copper, glass, electrically-conductive plastic, ceramics.

9. A sensor according to Claim 6, 7, or 8, characterized in that the pre-amplifier connected to each series is located in the space (44) between the electrode series in the immediate vicinity of each electrode series (27 - 29).

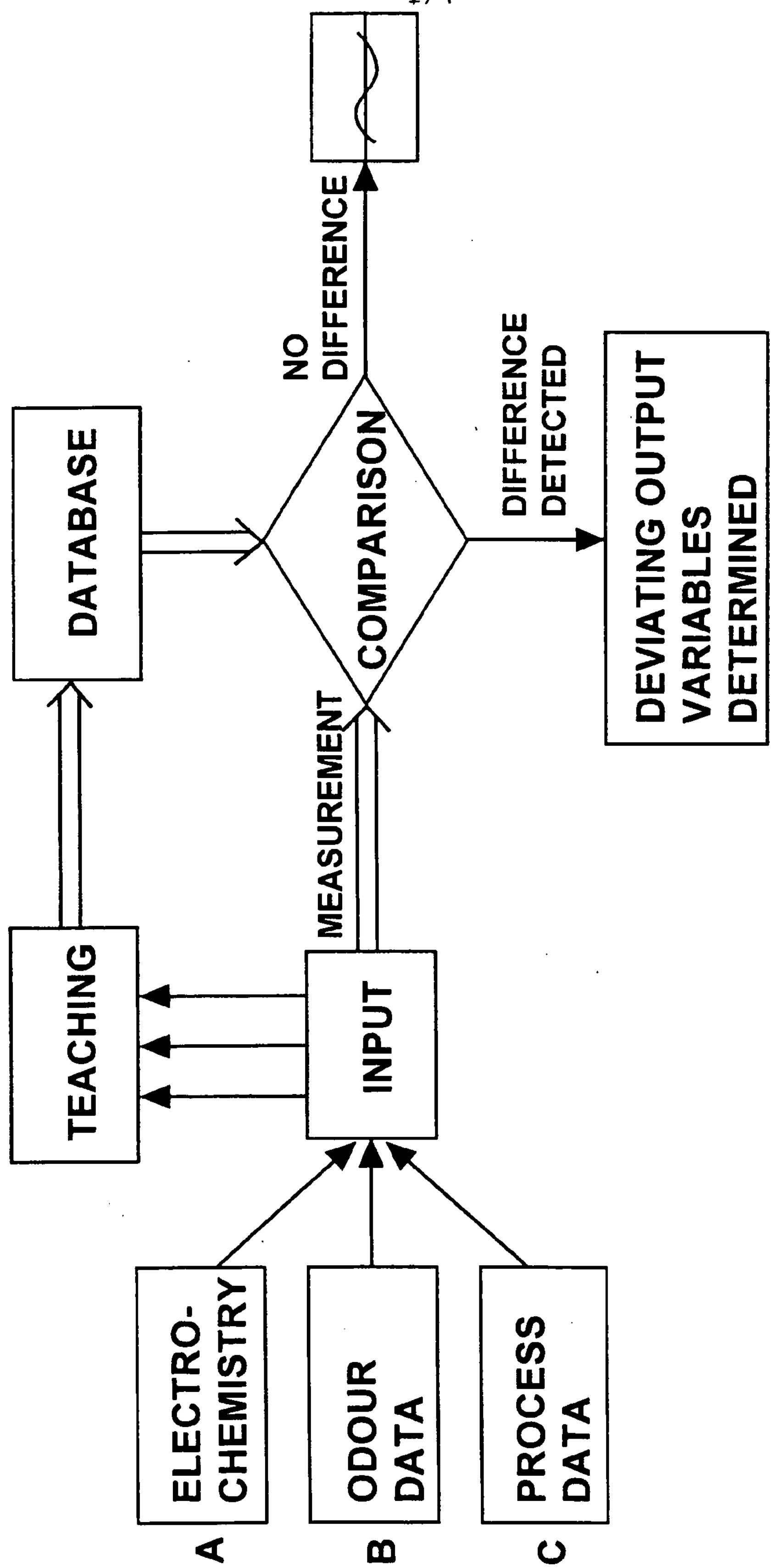
10. A sensor according to Claim 9, characterized in that the sensor includes an electrode cover (19) covering the radial channels (25) on at least one side, to which the electrodes are attached to extending into the said channels (25) and on the other side extending to a special electronic circuit card (40), in which the said pre-amplifiers are installed.

11. A sensor according to Claim 10, characterized in that a protectively ground cylinder, which extends over at least one-third of the depth of the electrode cover (19), is fitted around the electrodes (27 - 29) on the circuit card (40) side.

12. A sensor according to one of Claims 5 - 11, characterized in that the sensor pipes are arranged in such a way that liquid remains around the sensors during a shutdown.

13. A sensor according to one of Claims 6 - 8, characterized in that the radial channels (25) have a diameter of 0,3 - 3 cm, preferably 0,7 - 1,3 cm and each electrode (27 - 29) protrudes into the channel in such a way that the speed of flow increases substantially at it.

14. A sensor according to one of Claims 6 - 11, characterized in that the electrode (26) in the centre of the intake channel is a high-speed temperature sensor.


ELECTRO-
CHEMISTRY
ODOUR
DATA
PROCESS
DATA
A
B
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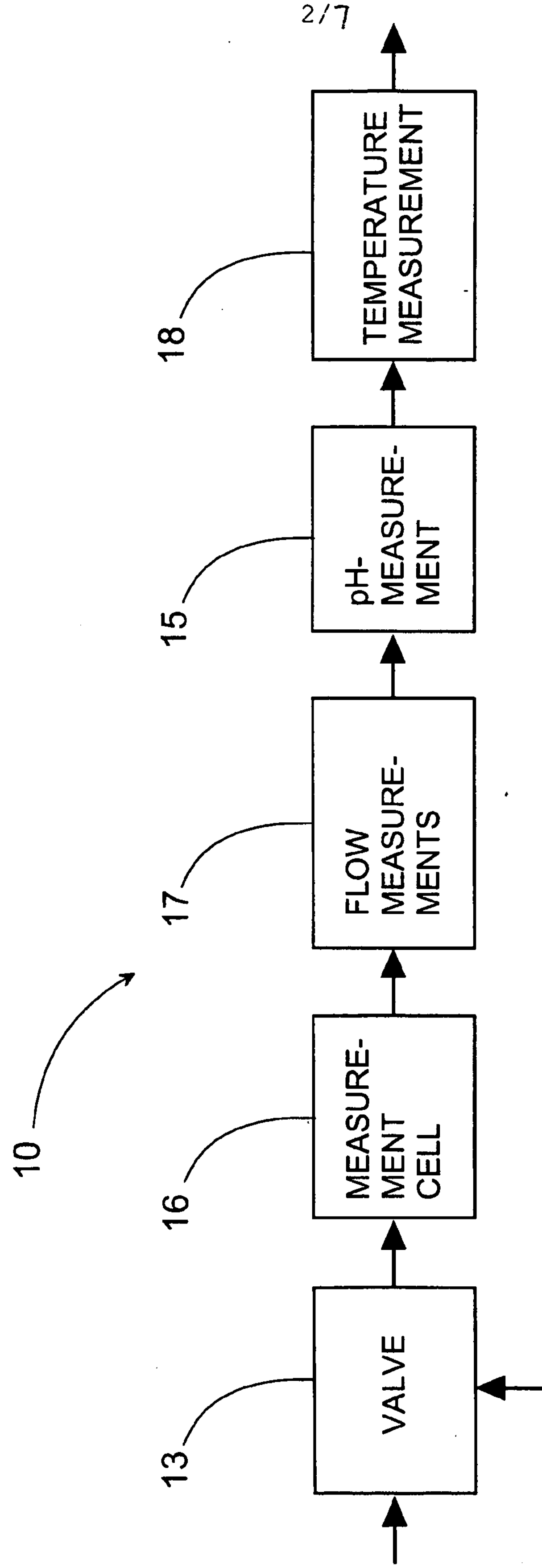
INPUT
TEACHING
MEASUREMENT
DATABASE
COMPARISON
NO
DIFFERENCE
DIFFERENCE
DETECTED
DEVIATING OUTPUT
VARIABLES
DETERMINED

Fig. 1



VALVE
MEASURE-MENT CELL
FLOW MEASURE-MENTS
pH-MEASURE-MENT
TEMPERATURE MEASUREMENT
10
13
16
17
15
18

Fig. 2

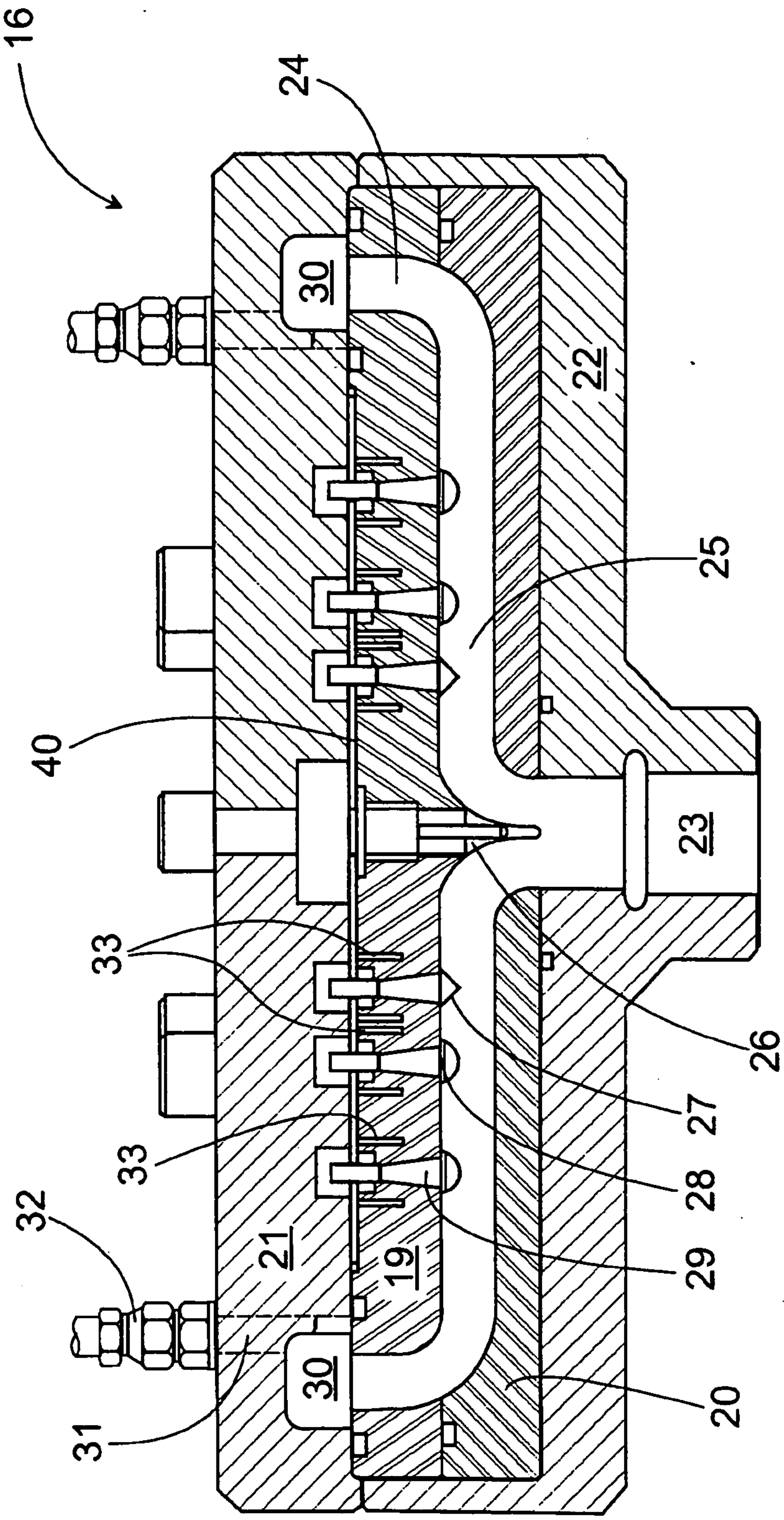


Fig. 3

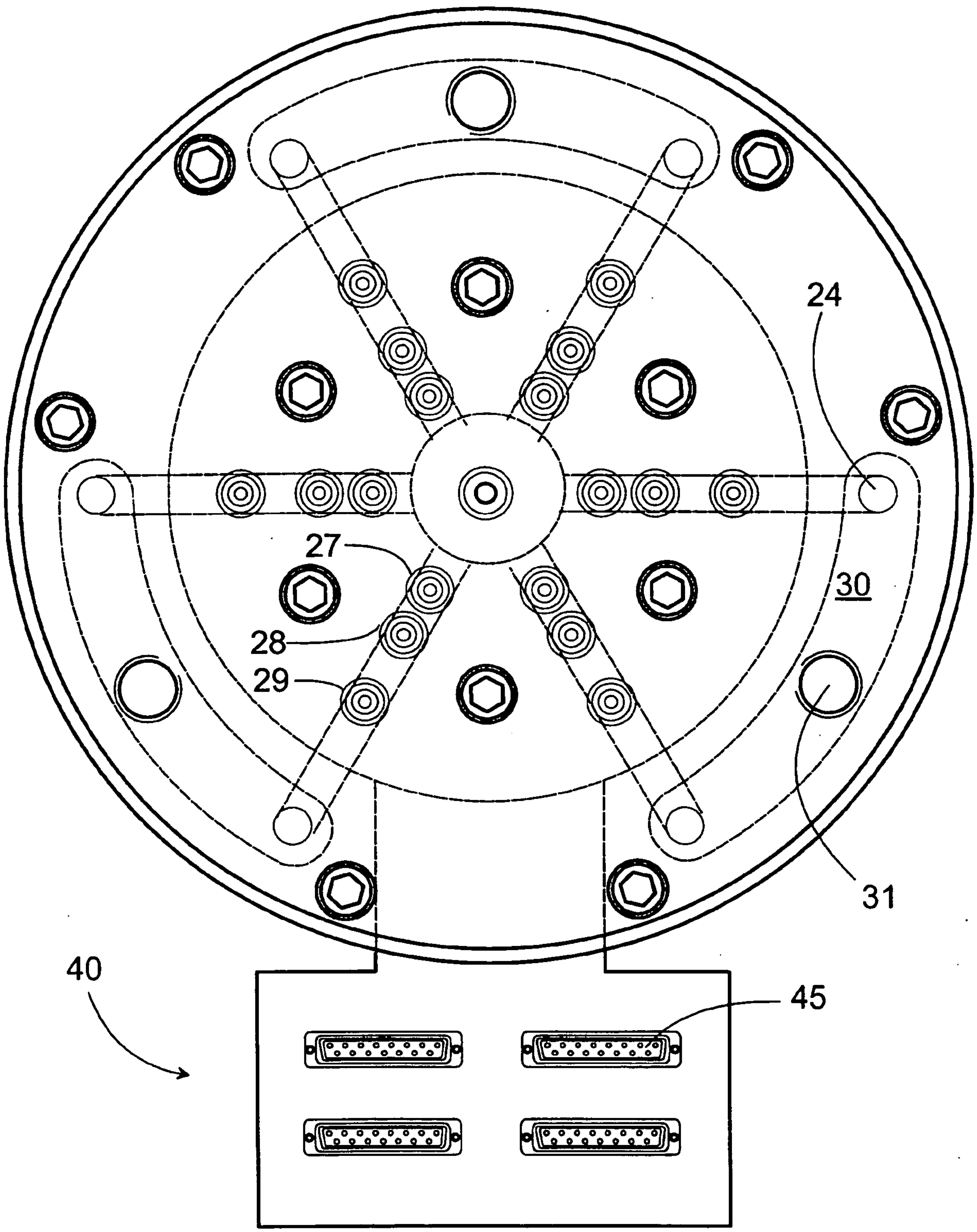


Fig. 4

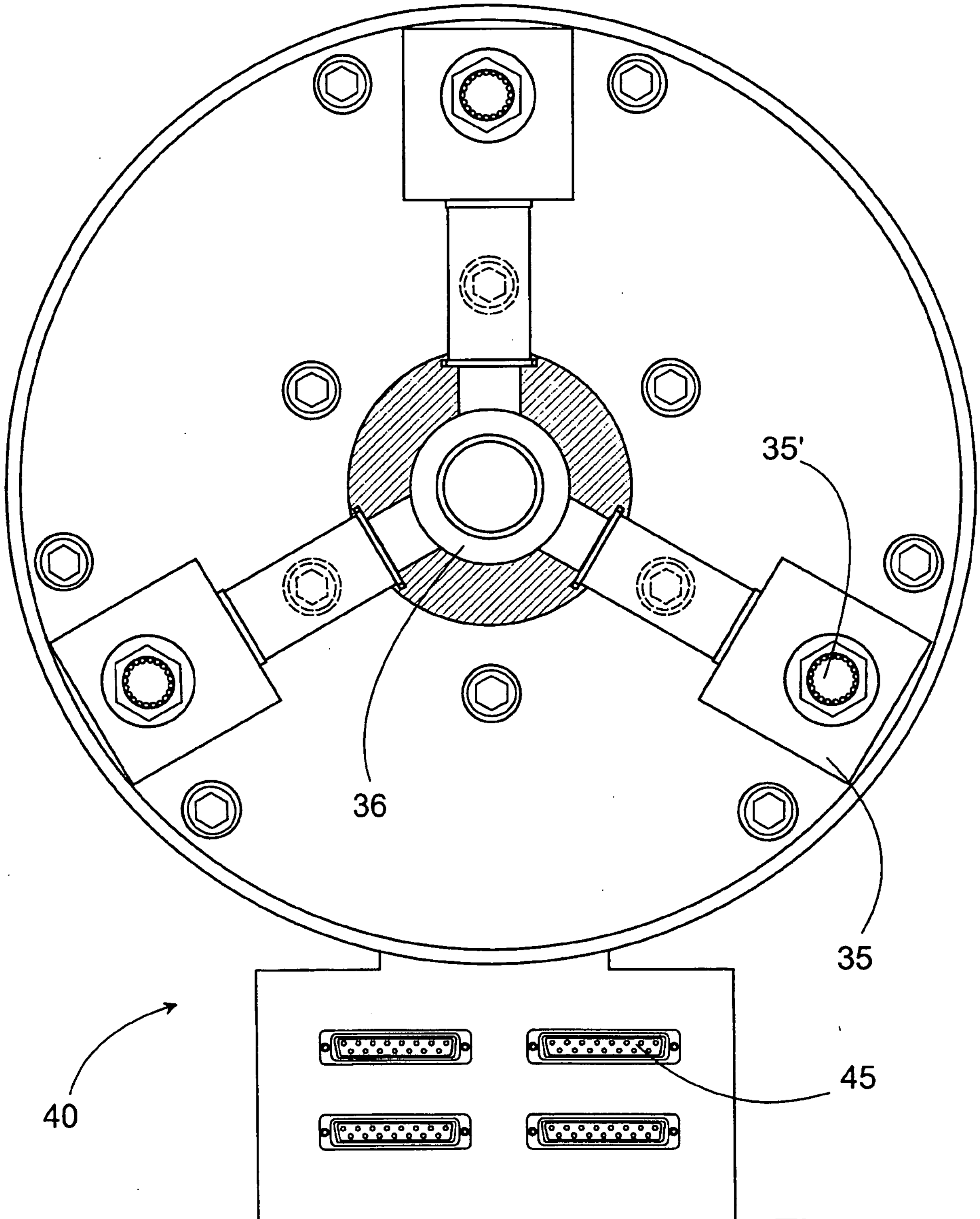


Fig. 5

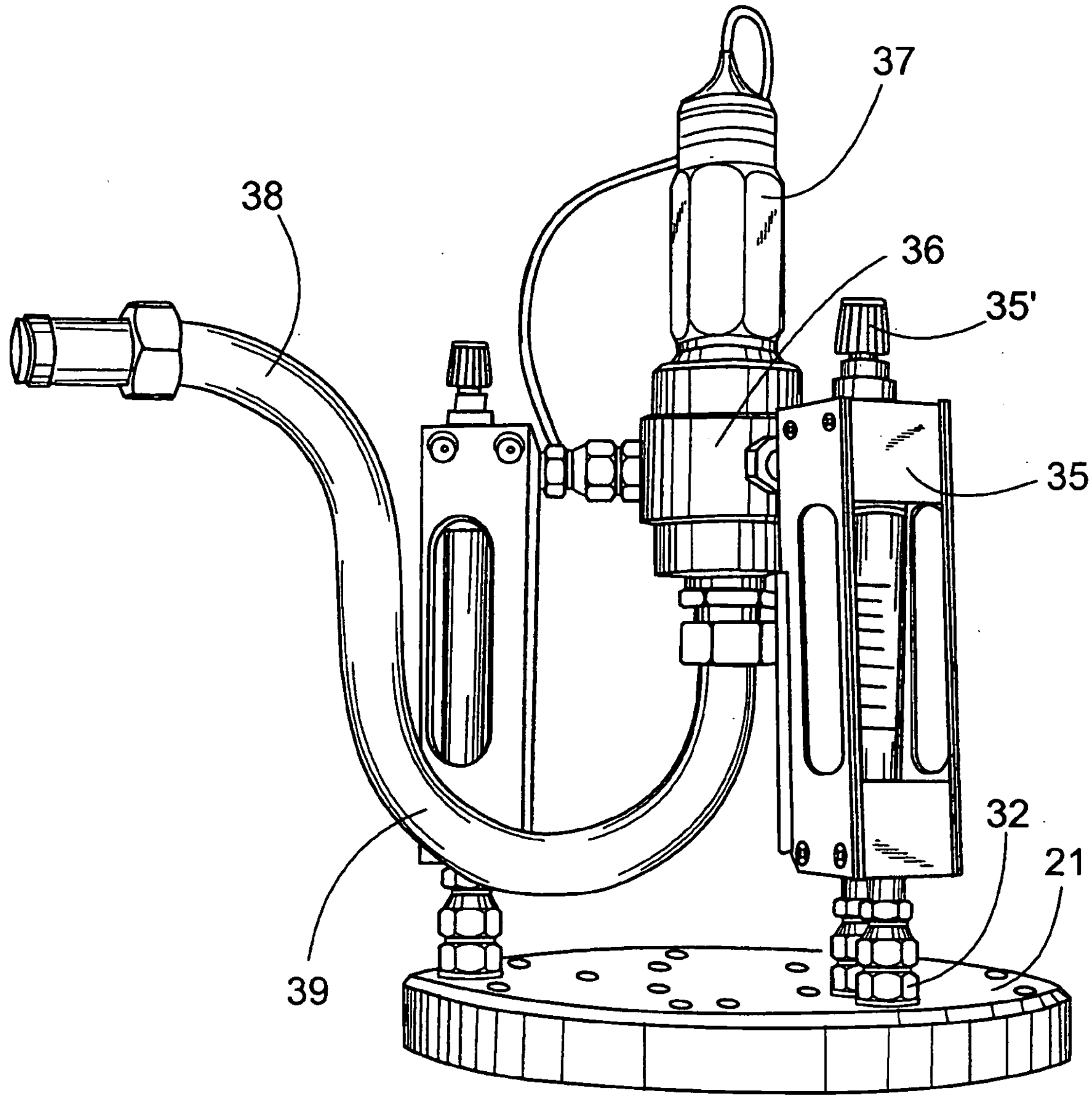


Fig. 6

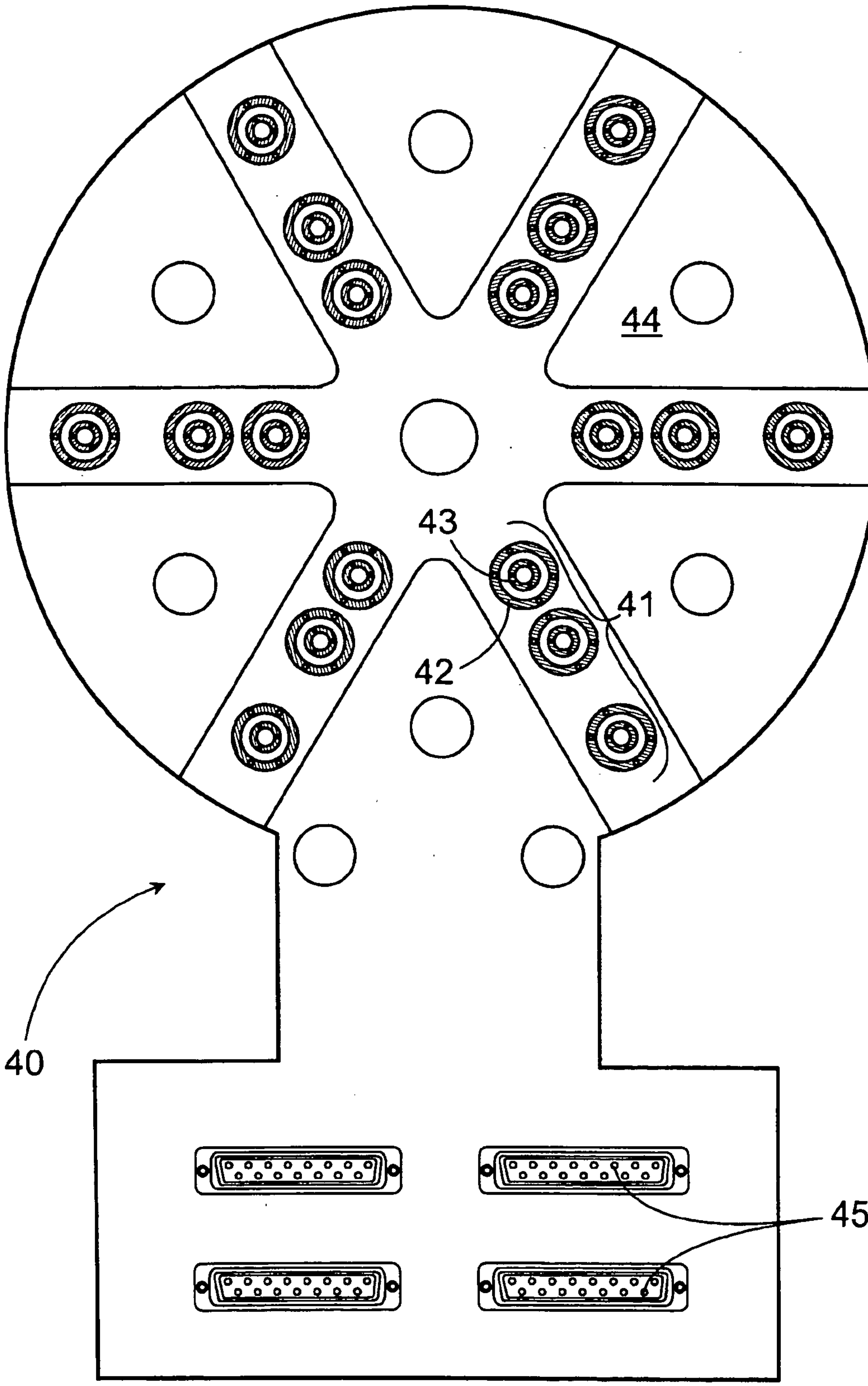


Fig. 7

INTERNATIONAL SEARCH REPORT

International application No.
PCT/FI 00/00861

A. CLASSIFICATION OF SUBJECT MATTER

IPC7: G01N 27/27, G01N 27/403, G01N 27/48, G01N 27/49 // G01N 33/34
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: G01N, B01L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

WPI,EPODOC,INSPEC,IEL

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
30 January 2001	08-02-2001

Name and mailing address of the ISA/	Authorized officer
Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666	Jonas Andersson /itw 8 782 25 00

INTERNATIONAL SEARCH REPORT

International application No.
PCT/FI 00/00861

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27/12/00

International application No.
PCT/FI 00/00861

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